Vertical Structure and Flux Formulations for the Stable Boundary Layer (DAAD19-0210224)

STATEMENT OF PROBLEM STUDIED

The main objectives are to provide improved understanding of the influence of intermittency and downward bursting of turbulence on the flux-gradient relationship, improve our conceptual view of the vertical structure of the boundary layer and turbulence generated by overlying shear not directly related to surface-based processes, identify the relative roles of advection of turbulence patches and local generation of turbulence and how these processes influence the local flux-gradient relationship, evaluate the turbulence kinetic energy budget and cospectral similarity theories and construct a substantially improved model of the nocturnal boundary layer, which includes both the surface-based boundary layer and z-less development of turbulence.

SUMMARY OF MOST IMPORTANT RESULTS

Our research over the past 2.5 years has substantially altered the way that we think about the stable nocturnal boundary layer and is also having a significant impact on the boundary-layer community. These results are based primarily on analysis of data from CASES99 and FLOSS. CASES99 has led to modification of almost every aspect of our conceptual and modeling framework for the stable boundary layer. Our most important conclusions are:

1. A z-less form of the mixing length, that approaches surface layer similarity theory at the surface and approaches boundary-layer similarity theory for weakly stratified conditions, performed significantly better than five other existing formulations, particularly after accounting for self-correlation. However, improvement to the overall boundary-layer performance in a regional model was not achieved because of previous tunning.

2. Radiative flux divergence was important for the initial formation of the surface inversion layer in CASES99 but was otherwise unimportant.

3. The success of Monin-Obukhov similarity theory with moderate and strong stability is mainly attributed to self-correlation.

4. The use of existing methods for computing fluxes with very weak turbulence in stable conditions is completely inadequate due to inadvertent inclusion of mesoscale motions and large random fluxes errors. The resulting erratic fluxes are generally discarded, removing the

b) PAPERS PUBLISHED IN CONFERENCE PROCEEDINGS

Mahrt, L. and D. Vickers, 2004: Semi-collapsed and advective stable boundary layers. paper 4.8 on CD. 16th Symposium on Boundary Layers and Turbulence, 9-13 August 2004, Portland, Maine, American Meteorological Society.

Mahrt, L. and D. Vickers, 2004: Mixing in Stable Conditions. 27th ITM - International Technical Meeting
on Air Pollution Modelling and its Application. Banff, Canada, 25 - 29 Oct, 2004, 278-285.

d) MANUSCRIPTS SUBMITTED

Mahrt, L. and D. Vickers, 2005: Extremely weak mixing in stable conditions. submitted to Bound-Layer Meteorol.
Vickers, Dean and L. Mahrt, 2005: A solution for flux contamination by mesoscale motions with very weak turbulence. submitted to Bound-Layer Meteorol.

TECHNICAL REPORTS; forwarded to ARO under separate cover

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13. ABSTRACT (Maximum 200 words)

A z-less form of the mixing length, that approaches surface layer similarity theory at the surface and approaches boundary-layer similarity theory for weakly stratified conditions, performed significantly better for CASES99 data than five other existing formulations, particularly after accounting for self-correlation. Radiative flux divergence was important for the initial formation of the surface inversion layer in CASES99 but was otherwise unimportant. Based on several data sets, the success of Monin-Obukhov similarity theory with moderate and strong stability is mainly attributed to self-correlation. The use of existing methods for computing fluxes with very weak turbulence in stable conditions is completely inadequate due to inadvertent inclusion of mesoscale motions and large random flux errors. More careful calculation of turbulence quantities for these conditions leads to extremely weak, but well behaved, turbulence fluxes. Intermittent turbulence patches are found to evolve and decay on small time scales and cannot be studied from a single tower. They advect past individual towers in various states of evolution and decay, which is one of several causes of the poor relationship between turbulence and the Richardson number. Well defined intermittent events seen in textbooks are in practice relatively rare. Most intermittency assumes a more complex behavior.

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